RECENT DEVELOPMENTS OF SMALL-SCALE SOLAR OR WASTE HEAT DRIVEN COOLING KITS FOR AIR-CONDITIONING AND REFRIGERATION

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Abstract

In the last three years SolarNext has developed standardized small-scale solar or waste heat driven cooling kits, so-called chillii® Cooling Kits. Different single-effect absorption and adsorption chillers are used as core component of such cooling kits. These are two ammonia/water absorption chillers with a cooling capacity of 12 kW and 50 kW respectively, the chillii® PSC12 and chillii® ACC50, a 17.5 kW water/lithium bromide absorber chillii® WFC18, two water/silica gel adsorption chillers with cooling capacities of 7.5 kW and 15 kW (chillii® STC8 and chillii® STC15) and two water/zeolith adsorption chillers chillii® ISC7 with 7 kW and chillii® ISC10 with 10 kW cooling capacity. Up to now over twenty chillii® Cooling Kits and chillii® Solar Cooling Kits respectively are in installed in Germany, Austria, Belgium, France, Spain, Italy, Malta, Romania, Canada, China and Australia. Different kinds of applications are realized like for residential buildings, retirement home, office buildings, bank, bakery, greenhouse, institutes and fish cooling. The sales mix shows that 81% of the installed cooling kits using solar heat from flat plate, vacuum tube or parabolic trough collectors as heat source and 19% are using waste heat from CHP units, ovens or ship engines.

1. Introduction

Worldwide the energy consumption for cold and air-conditioning is rising rapidly. Usual electrically driven compressor chillers (split-units) have maximal energy consumptions in peak-load period during the summer. In the last few years even in Europe this regularly leads to overloaded electricity grids. The refrigerants that are currently used in the split-units do not have an ozone depletion potential (ODP) anymore, but they have a considerable global warming potential (GWP), because of leakages of the chiller in the area of 5 to 15 % per year. Particularly the sale figures of split-units with a cooling capacity range up to 5 kW are rising rapidly. The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) has expected a worldwide sales of 82.3 million units in 2008. In Europe the number of sold units has risen about 37% from 6.3 million in 2004 to predicted 8.6 million in 2008 (JARN, 2008).

Thermal cooling by solar energy, district heat or waste heat from CHP units, biomass as well as processes could be lead to a considerable reduction of energy consumption. The sorption chillers use environmentally friendly refrigerants and have only very low electricity demand. Therefore the operating costs of these chillers are very low and the CO_2 balance compared to split-units is considerably better. In case of solar cooling the main advantage is the coincidence of solar irradiation and cooling demand. However, for thermal cooling e.g. by waste heat from a CHP unit the benefit is the longer operating time of the CHP unit itself and with that the increased electricity production. In general the market potential for small-scale solar/ thermal cooling kits is very large. But so far, only a small number of companies develop and offer standardised small-scale cooling kits for the European market up to a 50 kW cooling capacity.

2. Standardized Small-Scale Cooling Kits

During the last few years especially in Europe many new small-scale sorption chillers have been developed. Many of these absorption and adsorption chillers have now passed from the prototype phase to field tests and into the production. Today absorption chillers with capacities from 4.5 kW to 50 kW and adsorption chillers with capacities from 7 kW to 15 kW cooling capacity are available (Jakob, 2008). Table 1 shows the available chillii® chillers for the different chillii® Solar/ Thermal Cooling Kits.

Table 1 – Small-scale sorption chillers for chillii® Solar/ Thermal Cooling Kits

Product name	**chillii® ISC7 / chillii® ISC10**	**chillii® STC8 / chillii® STC15**	**chillii® PSC12**	**chillii® WFC18**	**chillii® ACC50**
Technology	adsorption	adsorption	absorption	absorption	absorption
Working pair	water/zeolith	water/silica gel	ammonia/water	water/LiBr	ammonia/water
Cooling capacity	7 and 10 kW	8 and 15 kW	12 kW	17.5 kW	50 kW
Heating temperature	65 / 60°C (ISC7) 85 / 77°C (ISC10)	72 / 65°C	85 / 78°C	88 / 83°C	115 / 105°C
Recooling temperature	27 / 31°C (ISC7) 27 / 32°C (ISC10)	27 / 32°C	24 / 29°C	31 / 35°C	25 / 30°C
Cold water temperature	18 / 15°C	18 / 15°C	12 / 6°C	12.5 / 7°C	-5 / -10°C
COP	0.54 (ISC7) 0.50 (ISC10)	0.60	0.62	0.70	0.55
Dimensions (LxDxH)	0.65 x 1.30 x 1.65 m³	0.79 / 0.79 x 1.06 / 1.34 x 0.94 / 1.39 m³	0.80 x 0.60 x 2.20 m³	0.60 x 0.80 x 1.77 m³	2.35 x 1.65 x 2.63 m³
Weight	370 kg	295 / 590 kg	350 kg	420 kg	1,600 kg
Electrical power	20 W	20 / 30 W	300 W	72 W	3,000 W

During the last two years SolarNext has developed several chillii® Cooling Kits based on the chillii® absorption and adsorption chillers. These cooling kits basically contain a chiller, a re-cooler, pump-sets and a system controller. The cooling kits are developed for the European market, whereas other re-coolers can be offered according to the country. Up to now 47% wet cooling towers, 33% dry re-coolers, 10% ground water and 10% other recooling solutions were realized worldwide to get rid of the recooling heat of the installed chillii® Cooling Kits.

Figure 1 – chillii® Cooling Kits PSC12 and ISC10 (sources: SolarNext)

Figure 1 shows the chillii® Cooling Kit PSC12 (ammonia/water absorber) and the chillii® Cooling Kit ISC10 (water/zeolith adsorber), which could be complemented by solar, cold storage and cold distribution packages. The chillii® Cooling Kits could be used for different applications according to the sorption technology. The applications are residential buildings, office buildings, hotels, commercial buildings, banks and bakeries as well as for process cooling e.g. milk or wine cooling.

For solar cooling kits the average value of specific collector surface of all market available kits is 4.2 m^2/kW cooling capacity (Epp, 2008). SolarNext recommend collector areas with 4.5 m^2/kW. The average value of all installed small to large-scale solar cooling systems in Europe until the year 2006 was 3.0 m^2/kW (Henning, 2007). An all-season use of renewable energy sources for domestic hot water, space heating and solar cooling is here indispensable. The solar fraction for the solar cooling kit should be more than 70%.

3. System Controller

For the development of standardized solar/ thermal cooling kits it is indispensable to use a system controller for the complete system. The previous solar cooling demonstration and pilot projects are using several single controllers e.g. for the solar thermal system, for the chiller, for the recooler and for the cold or heat distribution, which are together cost intensive and are not always operating optimal together. The alternative was until now an expensive PLC controller which had to be programmed for each single case. Because of that the SolarNext has decided in the year 2007 to develop an own system controller for the whole system (Figure 2), which has an influence from the automotive sector and is cheap and system oriented.

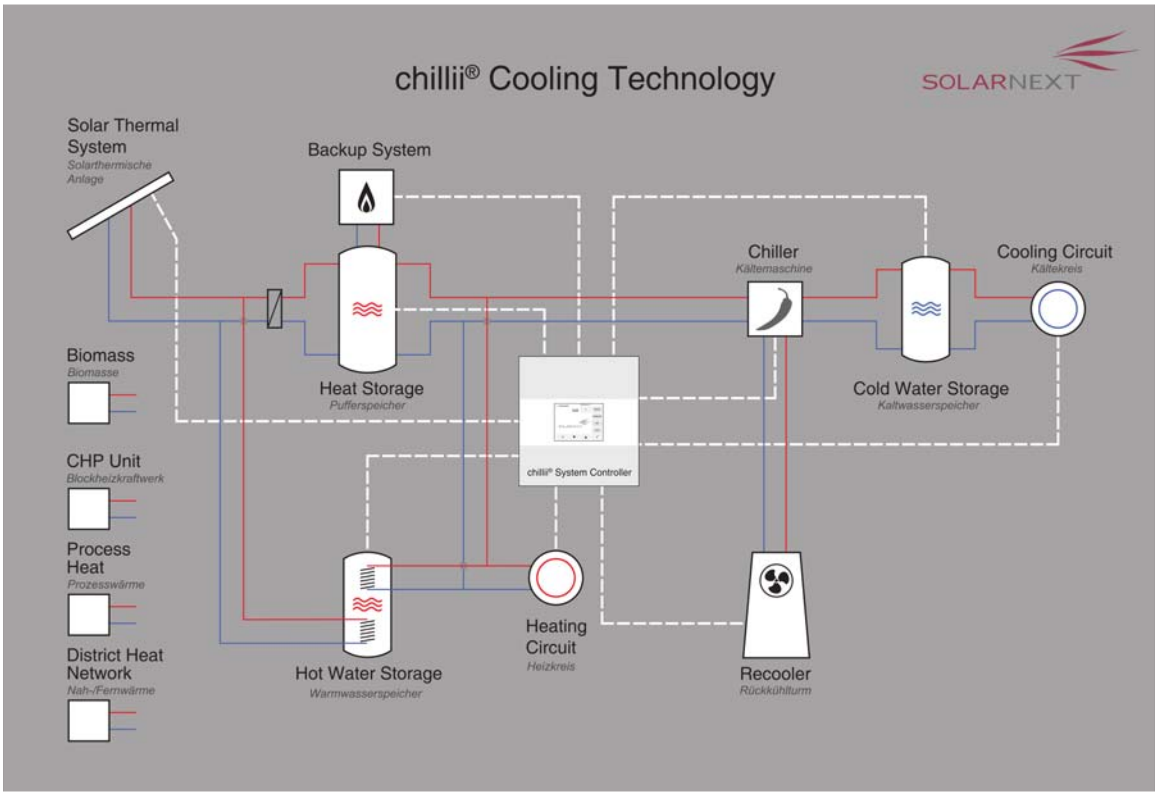

Figure 2 – chillii® Solar/ Thermal Cooling Kit scheme (source: SolarNext)

The functional range of the chillii® System Controller contains the control of different heat sources (e.g. solar heat, CHP waste heat, district heat, etc.), the back-up system (e.g. controllable oil/gas boiler or not controllable wood boiler or exhaust gas heat recovery), the storage management (heat and cold storage), the hot water, the chiller (e.g. chillii® ISC7, STC8, ISC10, PSC12, STC15, ESC15 WFC18, Yazaki WFC-SC10, etc.) and the re-cooling (e.g. wet, dry, and hybrid cooler) as well as heating and cooling circuits. The chillii® System Controller is the first system controller for thermal cooling and heating systems that controls many large hydraulic variables with one device. So the highest system efficiency is reached with the needed energy generation with priority in regenerative energy sources, optimized running of chillers as well as the re-cooling with speed control of the pumps and the re-cooling ventilator.

4 Realized Solar/ Thermal Cooling Projects

In May 2008 the worldwide first installation of a chillii® Cooling Kit STC8 for a two family house in Alzenau, Germany (Figure 3) was successfully put into operation. The necessary heat for driving the machine is provided by 24 m² flat collectors and a biomass back-up. As a buffer 2.000 litre hot water storage is used. An electrically high efficient dry re-cooler with water spraying is used for an effective re-cooling of the 22 kW waste heat of the adsorption chiller. The cold distribution is effected by fan coils. The chillii® Cooling Kit STC8 is until now besides others installed in residential and office buildings as well as a greenhouse in the following countries: Germany, Austria, Belgium, Italy and China.

Figure 3 – Flat plate collectors on the roof of a two-family-house in Germany as well as the adsorption chiller and the dry re-cooler of the chillii® Cooling Kit STC8 (sources: SolarNext)

For the retirement home in Kalkara, Malta a complete solar cooling kit has been installed in spring 2008. The chiller that is used is a chillii® PSC10 (Figure 4) for a required cooling load of 10 kW. The cold water is stored in a 1,000 l storage and distributed by fan coils. The solar heat is delivered by 38 m² flat plate collectors, which are mounted on the roof. Moreover, a 1,000 l hot water storage is used to as well as ground water for the recooling of 27 kW recooling water. Further chillii® PSC10 absorption chillers are installed in different thermally driven systems in Germany, Canada and Malta using solar heat or waste heat e.g. from CHP units. Since June 2008 the novel chillii® PSC12 is available on the market. This ammonia/water absorption chiller is installed for the first time as a complete solar cooling kit in Italy and since then also in Spain and France.

Figure 4 – chillii® Solar Cooling Kit PSC10 with flat plate collectors on the roof for space cooling of a retirement home in Malta (sources: SolarNext)

In 2008 a thermal cooling kit was installed at a bakery in Neckarsulm, Germany (Figure 5) using the waste heat of a heat recovery system in the exhaust gas of the ovens. The waste heat is stored in a 2,000 l hot water storage to provide the chillii® Cooling Kit WFC18 with heat. A wet cooling tower cools down 43 kW recooling water. The water/lithium bromide absorber is used for space cooling and other air-conditioning applications in combination with vacuum tube and parabolic trough collectors are also realized in Romania and Australia.

Figure 5 – Thermal cooling system of a bakery in Germany using a chillii® Cooling Kit WFC18 and waste heat from the exhaust gas of the ovens (sources: SolarNext)

Another application is a potato cooling, which was realized in Pforzheim, Germany in 2008 (Figure 6). The thermal cooling kit consist of the 50 kW ammonia/water absorption chiller congelo 50 (chillii® ACC50) and a wet cooling tower with 150 kW recooling capacity. The required heat for the system is provided by a CHP unit with 214 kW thermal capacity (192 kW electrical capacity). The waste heat is stored in a 10,000 litre hot water storage.

Figure 6 – Ammonia/water absorption chiller congelo 50 (chillii® ACC50) in combination with a CHP unit for potato cooling in Germany (sources: AGO)

In Wyong, New South Wales, Australia the worldwide first chillii® Cooling Kit ISC10 is installed in a heritage for space cooling of a coffee shop (Figure 7). The System is in operation since April 2009 consisting of 34.8 m² vacuum tube collectors, 1,500 l hot water storage, 500 l cold water storage and fan coils for the cold distribution. A dry re-cooler with water spraying is used to get rid of 30 kW recooling heat.

Figure 7 – Vacuum tube collectors on a special roof construction of a heritage in Australia as well as chillii® Cooling Kit ISC10 consisting of water/zeolith adsorption chiller and dry re-cooler with water spraying (sources: UrbanEnergy)

5. Conclusion

In the small-scale cooling capacity range with up to 50 kW several single-effect water/lithium bromide absorption chillers; two ammonia/water absorbers as well as two water/silica gel and two water/zeolith adsorption chillers are recently available on the European market. Therefore, the market potential for solar/thermal cooling kits with small-scale cooling capacity is very large, so that different companies are developing such kits for the product business. In case active cooling being necessary, the long running times of the sorption chillers are the key for economic efficiency of solar and thermal cooling kits. For residential buildings in Central Europe only about 50 to 200 cooling hours occur, whereas in the southern Mediterranean area as well as for some industrial and office buildings approximately 1,000 full load hours are necessary.

The specific total costs of the solar cooling kits of SolarNext (without installation costs and cold distribution) have been between 5,000 and 8,000 EUR/kW cooling capacity in 2007. In 2008 average system costs of around 4,000 to 4,500 EUR/kW were reached depending on the application and the site. A further cost reduction could be achieved in 2009, so that the current specific system costs are between 3,500 and 4,500 EUR/kW. The investment costs for a solar package (solar thermal collectors, heat storage, solar pumps, etc.) is 1,500 to 2,000 EUR/kW. Therefore, the specific total costs for thermal cooling kits of SolarNext are today between 1,500 and 3,000 EUR/kW.

References

Epp B, Solar Cooling Kits for Europe, *Global Solar Thermal Energy Council*, www.solarthermalworld.org, 2009

Henning H-M, Overview on solar cooling, *Proceedings of the 3rd European Solar Thermal Energy Conference – estec 2007*, Freiburg, Germany, 2007

JARN, World Air Conditioner Market: The 2007 Overview. *JARN*, No. 472-S, pp. 57-70, 2008

Jakob U, New concepts and promising technologies, *Proceedings of the International Conference Sustainable Cooling Systems: Solar Cooling*, TECHbase Vienna, Austria, pp. 70-75, 2008